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COMPUTER PROGRAM FOR CALCULATION OF INTEGRAL-MEAN-SLOPE CORRELATION PARAMETER

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A computer program has been developed which calculates an aircraft integral-mean-slope geometrical parameter from detailed information of aft-fuselage area distribution. The IMS parameter correlates with high subsonic and transonic drag measurements and is utilized as a measure of aircraft performance.

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S U M M A R Y

This report describes a computer code which calculates a geometry parameter from inputs of an air vehicle aft end area distribution. This parameter, called the "Integral-Mean-Slope" or IMS, was found to correlate well with high subsonic and transonic aft end drag measurements and is used as a predictor of pressure drag.

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INTRODUCTION AND BACKGROUND

The NAVAIRDEVCEN was tasked with an assignment from the Naval Air Systems Command to develop an accurate method of predicting aft-end fuselage drag of twin nozzle "fighter" type aircraft. A computer program (reference (a)) and several supporting documents (references (b), (c) and (d)) were developed, in addition to this report, as a result of the aft-end drag analysis methods. During the methodology development, it was clear that one of the major parameters which correlates well with the aft-end drag was the Integral Mean Slope (IMS).

This report presents a computer code which allows the user to compute the IMS from inputs of the vehicle geometry. The input format is compatible with other in-house graphics utility codes such as reference (g), so the user may preview the inputs before execution.

The IMS parameter is calculated by integration of the normalized rate of change of fuselage area as defined by the following equation.

$$IMS = \frac{\int_{A_E/A_{MAX}}^{1.0} \frac{d(A/A_{MAX})}{d(X/D_{EQ})} \, d(A/A_{MAX})}{1.0 - A_E/A_{MAX}} \qquad (1)$$

where,

A_E represents the aft area integration limit

A_{MAX} represents the maximum fuselage area

D_{EQ} represents the maximum equivalent fuselage diameter,

$$D_{EQ} = \left(\frac{4\ A_{MAX}}{\Pi}\right)^{1/2}$$

The IMS parameter was originally introduced by Pratt & Whitney Aircraft in reference (e) as a correlation parameter relating fuselage area distribution with the variation of aftbody drag coefficient. Another variant of the IMS is the truncated IMS or IMST which was formulated by Boeing in reference (f). The truncated IMS parameter is a recent variation of the basic IMS calculation which utilizes empirical data associated with probable streamline separation as a function of aftbody curvature and Mach number. The calculation procedure involves testing the local

aftbody slope at a given free stream Mach condition for the possibility of separation and the modification of the aftbody slope to conform to the separation streamline when appropriate. The empirical data associated with the truncated IMS parameter is presented in Figure 1 and was extracted from reference (f).

CODE OPERATION

The code consists of a main program, IMS, and two subroutines, SPLNQ1 and SLOPE1. IMS processes the input data to create an array of the normalized area distribution versus normalized aftbody length (see equation (1)). An integration is performed in accordance with equation (1) above in steps of .01 of the normalized aftbody length to arrive at the IMS and IMST.

The subroutines SPLNQ1 and SLOPE1 associated with this computer code utilize a spline fit curve through the input data to produce a piecewise cubic with continuous first and second derivatives. The aftbody area distribution is curve fitted using the SPLNQ1 subroutine for interpolation of data values and the calculated aftbody slope is obtained in a similar manner using the SLOPE1 subroutine.

OPERATING INSTRUCTIONS

The IMS parameter correlates well with high subsonic and transonic aftend drag measurements (see references (a) and (b)) if sufficient care is exercised in the precision of input data. The numerical calculation procedure necessitates a smooth input data curve of aftend area distribution for maximum precision of calculated IMS parameter. Therefore, it is advisable to plot the area distribution prior to use of this program to insure a smooth input curve. The data input format is compatible with the NAVAIRDEVCEN plotting computer codes (reference (g)) to facilitate the input of analytically smooth data curves.

The program input data requirements are specified in Table I, where a minimum of nine data cards are required for execution. The maximum integration limit (XMAX) is input in the first ten columns of card 1 and can represent either fuselage station directly or can be normalized with the maximum equivalent fuselage diameter. The number of Mach numbers (XNOMACH) is input in the next ten columns and the maximum fuselage area (AMAX) is entered in columns 21 thru 30.

The fuselage area distribution (input on card 7) can be specified in dimensional units of either square feet or square inches by setting the parameter (ADIMEN) in columns 31 thru 40 to either 0. or 1., respectively. The user may also input the normalized area distribution as a function of normalized aftbody length X/DEC, provided AMAX is input as 0. Detailed integration steps during the process of calculation of the overall IMS parameter can be printed by insertion of a value of 1. in columns 41 thru 50.

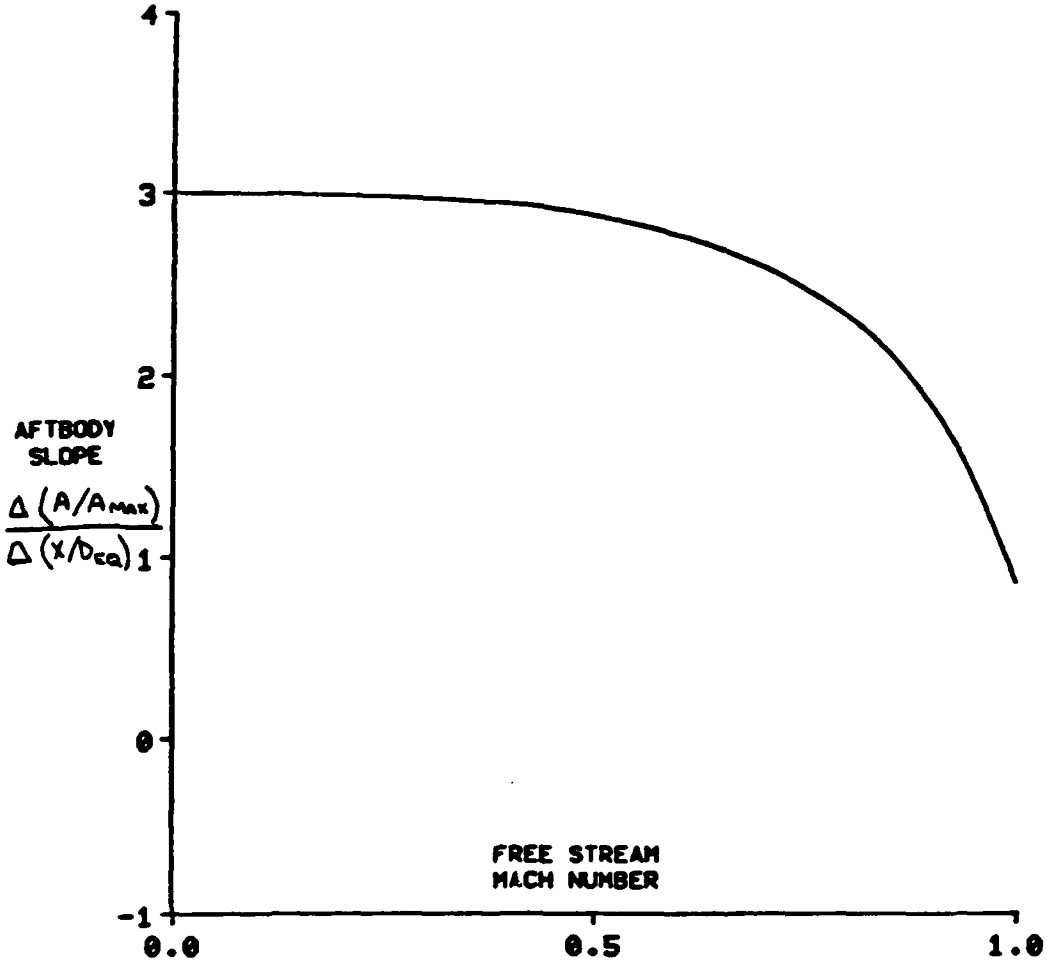

FIGURE 1 AFTBODY SEPARATION CRITERIA

TABLE I
INPUT DATA FORMAT FOR IMS PROGRAM

CARD	QUANTITY	MODE	COLUMNS	DESCRIPTION
1	XMAX	REAL	1-10	MAXIMUM INTEGRATION LIMIT, EITHER X/D (BODY DIAMETERS) OR FUSELAGE STATION - INCHES
	XNOMACH	REAL	11-20	NUMBER OF MACH NUMBERS
	AMAX	REAL	21-30	MAXIMUM OR REFERENCE AREA
	ADIMEN	REAL	31-40	CUE FOR DIMENSION OF AREA, 0. = SQ. FT., 1. = SQ. IN.
	XPRINT	REAL	41-50	CUE FOR DIAGNOSTIC PRINT, 0. = NO, 1. = YES
2	XM	REAL	1-10 11-20 . . . 71-80	MACH NUMBERS
3	IDENT	ALPHA-NUMERIC	2-80	CASE IDENTIFICATION TITLE
4	BLANK CARD			
5	BLANK CARD			
6	NPP	INTEGER	5-7	NUMBER OF X/DMAX DATA VALUES
	FX	REAL	11-20 21-30 . . . 71-80	X/DMAX DATA VALUES

TABLE I (CONT'D)
INPUT DATA FORMAT FOR IMS PROGRAM

CARD	QUANTITY	MODE	COLUMNS	DESCRIPTION
6 (CONT'D)	FX	REAL	11-20 21-30 . . . 71-80	ADDITIONAL X/DMAX DATA VALUES AS REQUIRED (FOR MORE THAN 14 DATA VALUES, CONTINUE KEYPUNCHING ADDITIONAL CARDS IN THE SAME MANNER)
7	NPP	INTEGER	5-7	NUMBER OF A/AMAX DATA VALUES
	FX	REAL	11-20 21-30 . . . 71-80	A/AMAX DATA VALUES
7a	FX	REAL	11-20 21-30 . . 71-80	ADDITIONAL A/AMAX DATA VALUES AS REQUIRED (FOR MORE THAN 14 DATA VALUES, CONTINUE KEYPUNCHING ADDITIONAL CARDS IN THE SAME MANNER)
8	BLANK CARD			

REPEAT CARDS 1 THROUGH 8 FOR EACH ADDITIONAL CASE

9	BLANK CARD			

The second data card is reserved for input of the Mach number values (XM) as real numbers in fields of 10 columns starting in column 1. The third data card allows the input of a case identification or title (IDENT) with cards four and five input with blank fields. The number of fuselage data stations (NPP) is input on card 6 as an integer value right-adjusted in columns 5 thru 7 with the fuselage data values (FX) input as monatomically increasing real numbers in fields of ten, starting in column 11. If necessary, additional fuselage data values can be continued on subsequent cards, starting each in column 11. The number of fuselage area data values (NPP) is input on card seven as a right-adjusted integer in columns 5 thru 7, and must correspond with the value input on card 6. The fuselage area data values (FX) are input in correspondence with the previously input fuselage values as real numbers in fields of ten starting in column 11. Additional fuselage data values can be entered on subsequent cards, starting each in column 11. The final card for each case is input with blank fields and additional cases can be included by repeating the input format of cards 1 through 8 followed by a blank stop card.

The output provided by the program consists of the standard IMS parameter calculation and the truncated IMS parameter for each Mach number specified by the user.

A sample case is included in Appendix A, together with the resulting sample output. A listing of the IMS source program and required subroutines are included in Appendix B.

REFERENCES

(a) Franz, J. J. and Lee, K. W., "Modified Twin Nozzle/Afterbody Drag and Nozzle Internal Performance Computer Program," NADC Report No. NADC-76405-30

(b) Franz, J. J., and Lee, K. W., "An Aftend Drag Data Base and Prediction Technique for Twin Jet Fighter Type Aircraft," NADC Report No. NADC-77021-30

(c) Franz, J. J., "Computer Program for Calculation of Airfoil Pressure and Turbulent Friction Drag," NADC Report No. NADC-77037-30

(d) Franz, J. J., "Analysis of Covariance Computer Program with Multiple Covariates and Forecast Capability," NADC Report No. NADC-77036-30

(e) Herrick, P. W., "Twin Jet Fighter Installed Nozzle Performance - A General Prediction Technique," Pratt & Whitney Aircraft, PWA-SMR-FR-3110, 22 Jan 1969

(f) Ball, W. H., "Propulsion System Installation Corrections," Air Force Flight Dynamics Laboratory, AFFDL-TR-72-147-Vol. IV, Dec 1972

(g) Caddy, M. J., "GPPR - A Multipurpose Comptuer Code for Data Plotting," NADC Report No. NADC-76367-30

APPENDIX A

SAMPLE INPUT/OUTPUT

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In this sample problem, the inputs on page A-5 show that the aft body area distribution was input in normalized form using 17 data sets terminating at a normalized aft body length of 2.611 equivalent diameters. From the inputs, we can see that the IMS was to be determined at 5 Mach numbers (.5, .6, .7, .8, and .9) from the maximum area station +. a length of 2.611 diameters. The IMS computation can be terminated at a more forward body station by specifying the parameter XMAX to be less than 2.611 in this case.

The output, on page A-6 shows the value of IMS and IMST to be .63665 over the Mach number range indicating no probable separation by the criterion discussed in the introduction section.

```
2.611     5.        0.0       1.

 .5       0.6       0.7       0.8       0.9

          SAMPLE IMST CALCULATION - AMAX TO NOZZLE EXIT STATIONS

Z      1  0.

Y      1  0.

X/DM  17  0.        .182      .41       .637      .865      .979      1.024

          1.07      1.206     1.434     1.662     1.889     2.108     2.231

          2.344     2.458     2.611

A/AM  17  1.        .9957     .9786     .9489     .9063     .8782     .8660

          .8544     .83003    .7889     .7193     .6448     .5696     .4942

          .403      .2828     .1017

EOT

 .0
```

```
SAMPLE IMS1 CALCULATION - AMAS TO NOZZLE EXIT STATIONS

2.61100   0.00000   1.00000

 .50000    .60000    .70000    .80000    .90000   0.00000   0.00000   0.00000

     17.0000

      0.0000    .1820    .4100    .6370    .8650    .9780   1.0240

      1.0700   1.2060   1.4340   1.6620   1.8890   2.1080   2.2310

      2.3440   2.4580   2.6110

      1.0000    .9957    .9786    .9489    .9063    .8782    .8660

       .8546    .8300    .7809    .7193    .6448    .5686    .4942

       .4030    .2828    .1017
```

MACH NO	TRUNCATED IMS	STD IMS
.5000	.63662	.63662
6000	.63662	.63662
.7000	.63662	.63662
.8000	.63662	.63662
.9000	.63662	.63662

APPENDIX B

COMPUTER LISTING

The listing provided herein includes the IMS program with subroutines SPLNQ1 and SLOPE1 which are currently operational on the NAVAIRDEVCEN CDC 6600 computer system.

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```
      PROGRAM IMS(INPUT,OUTPUT)                                           IMS 000
C                                                                         IMS 000
C*** THIS PROGRAM COMPUTES THE INTEGRAL MEAN SLOPE OF A GIVEN AREA         IMS 000
C     DISTRIBUTION                                                        IMS 000
C                                                                         IMS 000
      DIMENSION FX(303),Z(45),XM(8),IDUM(8),IDENT(8)                      IMS 000
      DATA Z/14 .                                                         IMS 000
     10 .,.1,.2,.3,.4,.5,.6,.7,.75,.8,.85,.9,.95,1.,                      IMS 000
     23.,3.,3.,2.98,2.94,2.87,2.75,2.58,2.45,2.30,2.09,1.78,1.40,.85 .    IMS 000
     30.,1.,1490./                                                        IMS 001
C                                                                         IMS 001
C*** XMAX IS THE MAX INTEGRATION LIMIT,EITHER X/D (BODY DIAMETERS) OR     IMS 001
C     FUSELAGE STATION-INCHES                                             IMS 001
C*** XNOMACH IS THE NUMBER OF MACH NUMBERS                                IMS 001
C*** AMAX IS THE MAXIMUM OR REFERENCE AREA                                IMS 001
C*** ADIMEN IS CUE FOR DIMENSION OF AREA,0 = SQ FT , 1 = SQ IN
C*** XPRINT IS CUE FOR DIAGNOSTIC PRINT,0 = NO, 1 = YES
C                                                                         IMS 001
      NPRT     = 0                                                        IMS 001
   10 READ 20,XMAX,XNOMACH,AMAX,ADIMEN,XPRINT                             IMS 001
   20 FORMAT(8F10.0)                                                      IMS 001
      IF(XMAX.EQ.0.) STOP                                                 IMS 002
      NM       = XNOMACH                                                  IMS 002
      IF(AMAX.NE.0.) GO TO 30                                             IMS 002
      AFAC     = 1.                                                       IMS 002
      DFAC     = 1.                                                       IMS 002
      GO TO 40                                                            IMS 002
   30 AFAC     = 1./AMAX                                                  IMS 002
      DFAC     = .0738522/SQRT(AMAX)                                      IMS 002
      IF(ADIMEN.NE.0.) DFAC= .88623/SQRT(AMAX)
C                                                                         IMS 002
C*** READ MACH ARRAY                                                      IMS 002
C                                                                         IMS 003
   40 READ 20 ,XM                                                         IMS 003
      IF(NPRT.EQ.0) PRINT 50                                              IMS 003
   50 FORMAT(1H1)                                                         IMS 003
      NPRT     = NPRT + 1                                                 IMS 003
C                                                                         IMS 003
C*** DATA TABLES ARE READ IN USING TREAD/TLOOK FORMAT FOR COMPATIBILITY    IMS 003
C     WITH PROGRAM TPLOT FOR PLOTTING                                     IMS 003
C                                                                         IMS 003
      READ 90,IDENT                                                       IMS 003
      PRINT 90,IDENT                                                      IMS 004
      PRINT 60                                                            IMS 004
   60 FORMAT(1H )                                                         IMS 004
      PRINT 70,XMAX,AMAX,ADIMEN                                           IMS 004
   70 FORMAT(8(1X,F10.5))                                                 IMS 004
      PRINT 70,XM                                                         IMS 004
      DO 80 J=1,2                                                         IMS 004
   80 READ 90,IDUM                                                        IMS 004
   90 FORMAT(8A10)                                                        IMS 004
      READ 100,NPP,(FX(I),I=2,8)                                          IMS 004
  100 FORMAT(4X,I3,3X,7F10.0)                                             IMS 005
      NP       = NPP + 1                                                  IMS 005
      FX(1)    = NPP                                                      IMS 005
      IF( NPP.GT.7) READ 110,(FX(I),I=9,NP)                               IMS 005
  110 FORMAT(10X,7F10.0)                                                  IMS 005
      J        = NP + 1                                                   IMS 005
      NP       = NP + NPP                                                 IMS 005
      JE       = J + 6                                                    IMS 005

      READ 100,NPP,(FX(I),I=J,JE)                                         IMS 005
      J        = JE + 1                                                   IMS 005
      IF(NPP.GT.7)READ 110,(FX(I),I=J,NP)                                 IMS 006
      READ 90,IDUM                                                        IMS 006
      FX(NP+1)= 0.                                                        IMS 006
      FX(NP+2)= 1                                                         IMS 006
      NP       = NPP + 1                                                  IMS 006
      PRINT 120,FX(1)                                                     IMS 006
      PRINT 120     ,(FX(I),I=2,NP)                                       IMS 006
  120 FORMAT(10X,7F10.4)                                                  IMS 006
      XSTRT    = FX(2)                                                    IMS 006
      XMAXX    = (XMAX-XSTRT)*DFAC                                        IMS 006
      IF(AFAC.EQ.1.) GO TO 140                                            IMS 007
      DO 130 I=2,NP                                                       IMS 007
  130 FX(I)    = (FX(I)-XSTRT)*DFAC                                       IMS 007
  140 J        = NP + 1                                                   IMS 007
      NP       = NP + NPP                                                 IMS 007
      PRINT 120     ,(FX(I),I=J,NP)                                       IMS 007
      PRINT 60                                                            IMS 007
      PRINT 150                                                           IMS 007
  150 FORMAT(T11*MACH NO*,T22*TRUNCATED IMS*,T40*STD IMS*)                IMS 007
      IF(AFAC.EQ.1.) GO TO 170                                            IMS 007
      DO 160 I=J,NP                                                       IMS 008
  160 FX(I)    = FX(I)*AFAC                                               IMS 008
  170 DO 220 I=1,NM                                                       IMS 008
      RMS      = 0                                                        IMS 008
      XMS      = -1.E20                                                   IMS 008
      DO 200 K=1,2                                                        IMS 008
      X=0                                                                 IMS 008
      RMS1     = RMS                                                      IMS 008
      DXS=DX=.01                                                          IMS 008
      AREA     = 0.                                                       IMS 008
      Y1       = SPLNQ1(1,FX,X)                                           IMS 009
      YS       = Y1                                                       IMS 009
      YP1      = SLOPE1(1,FX,X,YOUT2)                                     IMS 009
  180 IF((X+DX).GT.XMAXX) DX=XMAXX-X                                      IMS 009
      X        = X+DX                                                     IMS 009
      Y2       = SPLNQ1(1,FX,X)                                           IMS 009
      YP2      = SLOPE1(1,FX,X,YOUT2)                                     IMS 009
      IF(YP2.LT.XMS)  YP2=XMS                                             IMS 009
      AREA     = AREA+(YP1+YP2)*.5*(Y2-Y1)                                IMS 009
      IF(XPRINT.NE.0.)  PRINT 190,Y2,YP2,AREA                             IMS 009
  190 FORMAT(* A/AMAX=*E12.5,* SLOPE=*,E12.5,* AREA=*,E12.5)              IMS 010
      Y1       = Y2                                                       IMS 010
      YP1      = YP2                                                      IMS 010
      IF(DX.EQ.DXS) GO TO 180                                             IMS 010
      RMS      = AREA/(YS-Y1)                                             IMS 010
  200 XMS      = -SPLNQ1(1,Z,XM(I))                                       IMS 010
      PRINT 210,XM(I),RMS,RMS1                                            IMS 010
  210 FORMAT(6X,F10.4,5X,F10.5,5X,F10.5)                                  IMS 010
  220 CONTINUE                                                            IMS 010
      PRINT 230                                                           IMS 010
  230 FORMAT(1X,/////)                                                    IMS 011
      IF(NPRT.EQ.2) NPRT=0                                                IMS 011
      GO TO 10                                                            IMS 011
      END                                                                 IMS 011
      FUNCTION  SPLNQ1     (NLOC,X,KINDEP)                                SPLN000
C     CUBIC SPLINE FIT REVISED 10/21 71 M CADDY                           SPLN000
C     THIS VERSION HAS QAD OPTION WHERE ALL OF THE SPLINE COEFFICIENTS    SPLN000
C     ARE COMPUTED AND STORED IN THE ARRAY.  FOR N DATA POINTS 3*N+3      SPLN000
```

```
C     STORAGE LOCATIONS ARE REQUIRED FOR THE DATA AND THE COEFFICIENTS  SPLN000
C     NEW FEATURE IS QUICK LOOK-UP FOR LARGE ARRAYS                      SPLN000
      DIMENSION G(100),SB(100),X(1)                                      SPLN000
      XIN=XINDEP                                                         SPLN000
      NS=NLOC                                                            SPLN000
      NOPTS=X(NS)                                                        SPLN001
      ID=NS+NOPTS                                                        SPLN001
      NSP1=NS+1                                                          SPLN001
      NSP2=NS+2                                                          SPLN001
      NS2=NOPTS*2+NSP1                                                   SPLN001
      L=X(NS2)                                                           SPLN001
      LSC=NS2+1                                                          SPLN001
      IQMODE=X(LSC)                                                      SPLN001
      K=L                                                                SPLN001
      NL=NSP1                                                            SPLN001
      NH=ID                                                              SPLN002
      NTRAP=-1                                                           SPLN002
      IF(NOPTS.LE.1) GO TO 120                                           SPLN002
      IF(XIN-X(ID))20,130,10                                             SPLN002
   10 NTRAP=0                                                            SPLN002
      GO TO 130                                                          SPLN002
   20 IF(XIN-X(NSP1))130,40,50                                           SPLN002
   30 NTRAP=1                                                            SPLN002
   40 K=NSP2                                                             SPLN002
      GO TO 140                                                          SPLN002
   50 IF(L)110,110,60                                                    SPLN003
   60 IF(XIN-X(K))70,140,90                                              SPLN003
   70 NH=K                                                               SPLN003
      K=K-1                                                              SPLN003
   80 IF(XIN-X(K))100,140,90                                             SPLN003
   90 NL=K                                                               SPLN003
      GO TO 110                                                          SPLN003
  100 NH=K                                                               SPLN003
  110 K=(NH-NL)/2+NL                                                     SPLN003
      IF(K-NL)80,130,80                                                  SPLN003
  120 YOUT=X(NSP2)                                                       SPLN004
      GO TO 240                                                          SPLN004
  130 K=NH                                                               SPLN004
  140 M=K                                                                SPLN004
      X(NS2)=M                                                           SPLN004
      N=M+NOPTS                                                          SPLN004
      IF(L*IQMODE.GT.0) GO TO 210                                        SPLN004
  150 X2=X(NSP1)                                                         SPLN004
      X3=X(NSP2)                                                         SPLN004
      X32=X3-X2                                                          SPLN004
      Y3=X(ID+2)                                                         SPLN005
      Y32X32=(Y3-X(ID+1))/X32                                            SPLN005
      G(1)=0.                                                            SPLN005
      SB(1)=-.5                                                          SPLN005
      N1=NOPTS-1                                                         SPLN005
      IF(N1.LT.2) GO TO 170                                              SPLN005
      DO 160 I=2,N1                                                      SPLN005
      J=NSP1+I                                                           SPLN005
      K1=J+NOPTS                                                         SPLN005
      X1=X2                                                              SPLN005
      X2=X3                                                              SPLN006
      X21=X32                                                            SPLN006
      X3=X(J)                                                            SPLN006
      X32=X3-X2                                                          SPLN006
      Y2=Y3                                                              SPLN006

      Y3=X(K1)                                                           SPLN006
      Y21X21=Y32X32                                                      SPLN006
      Y32X32=(Y3-Y2)/X32                                                 SPLN006
      W=1./(2.*(X3-X1)-X21*SB(I-1))                                      SPLN006
      SB(I)=X32*W                                                        SPLN006
  160 G(I)=W*(6.*(Y32X32-Y21X21)-X21*G(I-1))                             SPLN007
  170 EM1=G(N1)/(2.+SB(N1))                                              SPLN007
      IF(L.GT.0) GO TO 180                                               SPLN007
      ID1=NOPTS                                                          SPLN007
      KQAS=NOPTS+LSC                                                     SPLN007
      X(KQAS)=EM1                                                        SPLN007
      GO TO 190                                                          SPLN007
  180 ID1=ID+2-M                                                         SPLN007
  190 DO 200 I=2,ID1                                                     SPLN007
      EM2=EM1                                                            SPLN007
      EM1=G(N1)-SB(N1)*EM2                                               SPLN008
      X(N1+LSC)=EM1                                                      SPLN008
  200 N1=N1-1                                                            SPLN008
      IF(L.GT.0) GO TO 220                                               SPLN008
  210 NSM=NS2+M-NS+1                                                     SPLN008
      EM1=X(NSM-1)                                                       SPLN008
      EM2=X(NSM)                                                         SPLN008
  220 S=X(M)-X(M-1)                                                      SPLN008
      IF(NTRAP.LT.0) GO TO 230                                           SPLN008
      IX=M-NTRAP                                                         SPLN008
      IY=IX+NOPTS                                                        SPLN009
      XS=XIN                                                             SPLN009
      XIN=X(IX)                                                          SPLN009
      Z1=X(M)-XIN                                                        SPLN009
      Z2=XIN-X(M-1)                                                      SPLN009
      YOUT=(((EM2*Z2*Z2-EM1*Z1*Z1)*.5+(X(N)-X(N-1)))/S                   SPLN009
     1-(EM2-EM1)*S/6.)*(XS-XIN)+X(IY)                                    SPLN009
      GO TO 240                                                          SPLN009
  230 Z2=XIN-X(M-1)                                                      SPLN009
      YOUT=(((EM2-EM1)*Z2+3.*S*EM1)*Z2+6.*(X(N)-X(N-1))-S*S*(EM1+EM1+    SPLN009
     1EM2))*Z2/(6.*S)+X(N-1)                                             SPLN010
  240 SPLNQ1=YOUT                                                        SPLN010
      RETURN                                                             SPLN010
      END                                                                SPLN010
      FUNCTION  SLOPE1    (NLOC,X,XINDEP,YOUT2)
C     CUBIC SPLINE FIT REVISED 10/21/71 M CADDY                              000
C     THIS VERSION HAS QAD OPTION WHERE ALL OF THE SPLINE COEFFICIENTS       000
C     ARE COMPUTED AND STORED IN THE ARRAY   FOR N DATA POINTS 3*N+3         000
C     STORAGE LOCATIONS ARE REQUIRED FOR THE DATA AND THE COEFFICIENTS       000
C     NEW FEATURE IS QUICK LOOK-UP FOR LARGE ARRAYS                          000
      DIMENSION G(100),SB(100),X(1)                                          000
      XIN=XINDEP                                                             000
      NS=NLOC                                                                000
      NOPTS=X(NS)                                                            001
      ID=NS+NOPTS                                                            001
      NSP1=NS+1                                                              001
      NSP2=NS+2                                                              001
      NS2=NOPTS*2+NSP1                                                       001
      L=X(NS2)                                                               001
      LSC=NS2+1                                                              001
      IQMODE=X(LSC)                                                          001
      K=L                                                                    001
      NL=NSP1                                                                001
      NH=ID                                                                  002
      NTRAP=-1                                                               002
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      IF(NOPTS-1)130,130,10                                    002
10    IF(XIN-X(ID))30,140,20                                   002
20    NTRAP=0                                                  002
      GO TO 140                                                002
30    IF(XIN-X(NSP1))40,50,60                                  002
40    NTRAP=1                                                  002
50    K=NSP2                                                   002
      GO TO 150                                                002
60    IF(L)120,120,70                                          003
70    IF(XIN-X(K))80,150,100                                   003
80    MM=K                                                     003
      K=K-1                                                    003
90    IF(XIN-X(K))110,150,100                                  003
100   NL=K                                                     003
      GO TO 120                                                003
110   MM=K                                                     003
120   K=(MM-NL)/2+NL                                           003
      IF(K-NL)90,140,90                                        003
130   YOUT=X(NSP2)                                             004
      GO TO 260                                                004
140   K=MM                                                     004
150   M=K                                                      004
      X(NS2)=M                                                 004
      N=M+NOPTS                                                004
      IF(L*IQMODE)160,160,220                                  004
160   X2=X(NSP1)                                               004
      X3=X(NSP2)                                               004
      X32=X3-X2                                                004
      Y3=X(ID+2)                                               005
      Y32=Y3-X(ID+1)                                           005
      G(1)=0                                                   005
      SB(1)=-.5                                                005
      N1=NOPTS-1                                               005
      DO 170 I=2,N1                                            005
      J=NSP1+I                                                 005
      K1=J+NOPTS                                               005
      X1=X2                                                    005
      X2=X3                                                    005
      X21=X32                                                  006
      X3=X(J)                                                  006
      X32=X3-X2                                                006
      Y2=Y3                                                    006
      Y3=X(K1)                                                 006
      Y21=Y32                                                  006
      Y32=Y3-Y2                                                006
      W=(X3-X1)/3. -X21*SB(I-1)/6.                             006
      SB(I)=X32/(W*6.)                                         006
170   G(I)=(Y32/X32-Y21/X21-X21*G(I-1)/6.)/W                   006
      EM1=G(N1)/(2.+SB(N1))                                    007
      IF(L)180,180,190                                         007
180   ID1=NOPTS                                                007
      KQAS=NOPTS+LSC                                           007
      X(KQAS)=EM1                                              007
      GO TO 200                                                007
190   ID1=ID+2-M                                               007
200   DO 210 I=2,ID1                                           007
      EM2=EM1                                                  008
      EM1=G(N1)-SB(N1)*EM2                                     008
      X(N1+LSC)=EM1                                            008
210   N1=N1-1                                                  008

      IF(L)220,220,230                                         008
220   NSM=NS2+M-NS+1                                           008
      EM1=X(NSM-1)                                             008
      EM2=X(NSM)                                               008
230   S=X(M)-X(M-1)                                            008
      IF(NTRAP)250,240,240                                     008
240   IX=M-NTRAP                                               008
      IY=IX+NOPTS                                              009
      XS=XIN                                                   009
      XIN=X(IX)                                                009
      Z1=X(M)-XIN                                              009
      Z2=XIN-X(M-1)                                            009
      YOUT=(((EM2*Z2*Z2-EM1*Z1*Z1)/2.+ X(N)-X(N-1))/S          009
     1-(EM2-EM1)*S/6.)                                         009
      YOUT2    = 0.
      GO TO 260                                                009
250   Z2=XIN-X(M-1)                                            009
      Z1=X(M)-XIN                                              009
      YOUT=(((EM2*Z2*Z2-EM1*Z1*Z1)/2.+ X(N)-X(N-1))/S
     1-(EM2-EM1)*S/6.)
      YOUT2    = (EM2*Z2+EM1*Z1)/S
260   SLOPE1=YOUT
      RETURN                                                   010
      END                                                      010
```